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Development of novel type of two-stage adsorption chiller with different adsorbents

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Abstract

Adsorption refrigeration has attracted considerable efforts over the past few decades. Adsorption refrigeration is considered as green refrigeration technology, which is driven by low grade heat source. Intensified efforts were promoted to improve the adsorption chiller performance in recent years. Two stages with different adsorbents adsorption chiller working principle and test were proposed in this paper. The novel adsorption chiller contains 4 pieces adsorbers and evaporator and condenser. Zeolite and actived carbon were applied for adsorbents in the two-stage cycle and two adsorbers were packed with zeolite and other adsorbers with actived carbon. The two-stage cycle can be operated effectively with 50℃, even with 45℃. Coefficient of performance (COP) and volumetric cooling power (VCP) of two-stage adsorption chiller with different operation conditions were investigated in this paper. The results showed that VCP increases firstly and then decreases with increasing the elapsed time and the maximum of VCP with driving heat source temperature of 50℃ and cooling water temperature of 30℃ and chilled water temperature of 15℃ was about 0.2 kW/L. The COP with driving heat source temperature of 45℃ was much higher than that of 50℃.

Keywords: Adsorption chiller, two-stage, Zeolite, Actived carbon.

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1. Introduction

Adsorption refrigeration is considered as green refrigeration technology, which is driven by low grade heat source. And adsorption refrigeration can utilize waste heat and solar energy to save energy, and other advantage is protecting environment without using CFC. Basic cycle of adsorption chiller contains two pieces adsorbers and evaporator and condenser, and generates cooling power continuously. Abdual Hadi N.Khalifa[1], H.T.Chua[2] and Z.Z.Xia[3] also discussed two beds of adsorption chiller performance. Advanced cycles were studied to enhance adsorption chiller performance. B.B.Saha[4-6] designed a dual-model, multi-stage, multi-bed, silica gel-water adsorption chiller which can utilize effectively low temperature solar or waste heat sources. The performance of a two-stage adsorption chiller with different mass allocation between upper and bottom beds had been investigated numerically [7]. It was found that the chiller can be driven effectively by the waste heat of temperature 55°C and the cooling capacity could be improved. And other two-stage cycles [8-9] were studied to improve chiller COP or decrease the driving sources temperature. All the above-mentioned cycles of adsorption chiller utilized one type adsorbent in one chiller respectively. In this paper, two-stage with two kinds of adsorbents of adsorption chiller was proposed which can be operated effectively with 50°C, even with 45°C.

2. Content

2.1. Working principle

The structural diagram of chiller is showed in Fig.1. The novel adsorption chiller contained 4 pieces adsorbers and evaporator and condenser. Zeolite and actived carbon were applied for adsorbents in the two-stage cycle and two adsorbers were packed with zeolite and other adsorbers with actived carbon.

The system working process included three sections which were evaporation / adsorption process, secondary desorption/adsorption process and desorption/ condensation process.

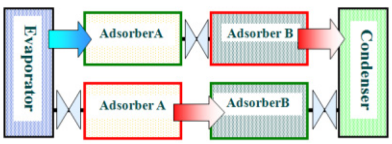


Fig.1 Structural diagram of adsorption chiller

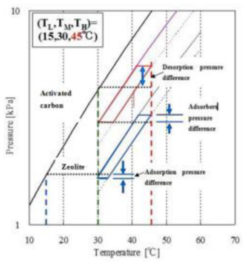


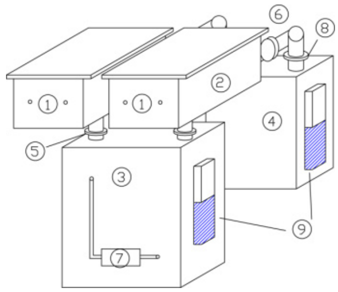
Fig.2 Pressure differences in the adsorption chiller

The pressure difference can drive the vapor moving in the adsorption chiller to control the chiller working. Pressure differences in the adsorption chiller were demonstrated in Fig.2 with driving heat source temperature of 45°C and cooling water temperature of 30°C and chilled water temperature of 15°C.

It was indicated that the first process with the above conditions can achieve with the saturated vapor pressure of 15°C higher than zeolite adsorption pressure of 30°C. Then the first process can realize logically. And the pressure difference between the desorption process of zeolite and the adsorption process of activated carbon was considerable. It meant that the vapor diffusion between two adsorbers can occur in the second process. The desorption pressure of activated carbon was obviously higher than that of condensation during the third process. Generally, it was intimated that two-stage adsorption chiller in this paper can generate cooling power with driving heat source temperature of 45℃.

2.2. Experimental

Fig.3 shows the setup diagram of adsorption chiller with two-stage cycle which contained 4 pieces adsorbers. And zeolite and actived carbon were applied for adsorbents in the two-stage cycle and two adsorbers were packed with zeolite and other adsorbers with actived carbon. The driving heat source temperatures (T_H) were chosen as 45℃ and 50℃. And cooling water (T_M) temperatures was 30℃and chilled water (T_L) temperatures was 15℃.



① Adsorber ②Heat Exchanger ③Condenser ④Evaporator ⑤⑥Vacuum valve ⑦Magnetic pump ⑧Valve ⑨Level gage

Fig.3 Setup diagram of adsorption chiller

3. **Results and discussions**

The performances of volumetric cooling power (VCP) and coefficient of performance (COP) of two-stage adsorption chiller with different operation conditions were investigated in this paper. And it was also verified by experiment that the two-stage adsorption chiller can work on driving source temperature of 45℃. Fig.4 showed experimental VCP of adsorbent of two-stage adsorption chiller. It was found that the VCP profiles of two different heat sources can present the similar variation with elapsed time. The value of VCP can increase firstly and then decrease with increasing elapsed time. The maximum of VCP with driving heat source temperature of 50℃ and cooling water temperature of 30℃ and chilled water temperature of 15℃ was about 0.2 kW/L.

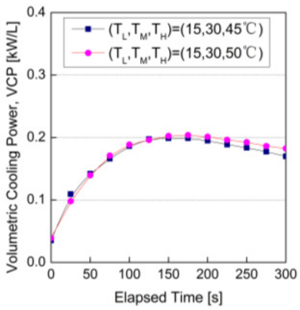


Fig.4 Effect of elapsed time on VCP with different driving source temperatures

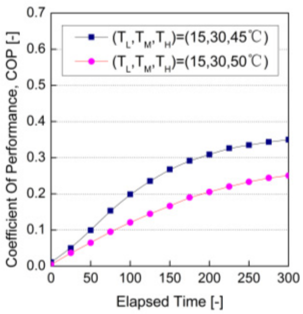


Fig.5 Effect of elapsed time on COP with different driving source temperatures

Fig.5 showed the effect of elapsed time on COP with different driving source temperatures. Under the experimental conditions, the COP with heat source temperatures of 45℃ and 50℃ presented increasing trend with enlarging the elapsed time, respectively. The COP with driving heat source temperature of 45℃ was obviously higher than that of 50℃ in the Fig.5. Output cooling power and heat consumption in the chiller system can control the system COP. The reason for the COP of 45℃ better than that of 50℃ was that decreasing the heat source temperature can benefit lowing heat loss, and heat consumption is the leading role.

4. Conclusions

The new type of adsorption chiller with two-stage working principle and experimental test were investigated in this paper which contained 4 pieces adsorbers. And two types of adsorbents were utilized in the chiller. It was verified by experiment that the two-stage adsorption chiller can work on driving source temperature of 45℃. The maximum of VCP with driving source temperature of 50℃ and cooling water temperature of 30℃ and chilled water temperature of 15℃ was about 0.2kW/L. The COP with driven source temperature of 45℃ was much higher than that of 50℃.

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Biography

H.Y. Huang is a professor, Guangzhou Institute of Energy Conversion, Chinese Academy of Sciences. He obtained his M.Sc. and Ph.D. degrees in energy engineering from Nagoya University. His research interests include adsorption heat pump, chemical heat pump and dehumidification.